

3 Site Planning and Layout

IN THIS CHAPTER...

- Road, driveway, and parking layouts for medium to high density subdivisions, large lots, and commercial sites
- Road crossings
- Street trees
- Lot layout for medium to high density clusters, large lots, and rural clusters
- Building design

Site assessment and site planning are iterative processes. Existing and native environmental conditions strongly influence the extent and location of the development envelope for a low impact development (LID) project. The regulatory, market, and architectural context of the location are integrated with the site assessment findings to produce a road and lot configuration that strategically uses site features for isolating impervious surface and dispersing and infiltrating storm flows. As site planning progresses and details for roads, structures, and LID practices are considered, additional evaluation of site conditions may be necessary.

Context is essential for developing any successful residential or commercial project. The designer must consider the appropriate plat design and housing type given the existing character and possible future conditions of the area when developed. Architectural considerations influence how the project integrates with the surroundings while at the same time creating neighborhood identity (personal communication Len Zickler, January 2004). A low impact development project incorporates these same design considerations; however, the following stormwater and other environmental management elements are elevated to equal standing:

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- Hydrology is an organizing principle that is integrated into the initial site assessment and planning phases.
- Individual LID practices are distributed throughout the project site and influence the configuration of roads, house lots, and other infrastructure.
- LID practices are amenities that provide multiple functions, including aesthetic landscaping, visual breaks that increase a sense of privacy within a variety of housing densities, and a design element (of equal importance to architectural and plat design) that promotes neighborhood identity.

Assessment of natural resources outlined in the previous section will produce a series of maps identifying streams, lakes, wetlands, buffers, steep slopes, and other hazard areas, significant wildlife habitat areas, and permeable soils offering the best available infiltration potential. Maps can be combined as GIS or CAD layers to delineate the best areas to direct development. Building sites, road layout, and stormwater infrastructure should be configured within these development areas to minimize soil and vegetation disturbance and take advantage of a site's natural stormwater processing capabilities.

Initial site management strategies include:

- Establish limits of disturbance to the minimum area required for roads, utilities, building pads, landscape areas, and the smallest additional area needed to maneuver equipment.
- Map and delineate natural resource protection areas with appropriate fencing and signage to provide protection from construction activities.
- Meet and walk the property with the owner, engineers, landscape architects, and others directing project design to identify problems and concerns that should be evaluated for developing the site plans.
- Meet and walk the property with equipment operators prior to clearing and grading to clarify construction boundaries and limits of disturbance (see Chapter 4: Vegetation Protection, Reforestation, and Maintenance and Chapter 5: Site Clearing and Grading for more detailed information).

The following section is organized under two main categories: (1) Roads, Driveways and Parking; and (2) Lot Layout. The first category is examined by medium to high density, individual large lot, and commercial type development, and the second by medium to high density cluster, rural cluster, and large lot development.

3.1 Roads, Driveways and Parking

Residential roads in the early 1900s were primarily laid out in grid patterns to allow efficient access to services and transit, and were dominated by a mix of uses including pedestrian, bicycle, and vehicle transportation. The grid configuration has evolved over the past century to modified grids and the current prevailing designs that use curvilinear layouts with relatively disconnected loops and cul-de-sacs. The transition has been driven primarily by the increased mobility offered by the automobile and the perceived safety and privacy of dead end roads (Canadian Mortgage and Housing Corporation [CMHC], 2002).

An analysis in south Puget Sound found that the transportation component of the suburban watershed accounts for approximately 60 percent of the total impervious area (City of Olympia, 1995). At the national level, the American Association of State Highway and Transportation Officials (AASHTO) estimates that the urban and rural local access roads typically account for 65 to 80 percent of the total road network (AASHTO, 2001). Design standards for roads in residential areas focus on efficient and safe movement of traffic and rapid conveyance of stormwater. As a result, streets contribute higher storm flow volumes and pollutant loads to urban stormwater than any other source area in residential developments (City of Olympia, 1995 and Bannerman, Owens, Dodds and Hornewer, 1993).

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The overall objectives for low impact development road designs are:

- Reduce **total impervious area** (TIA) by reducing the overall road network coverage.
- Minimize or eliminate effective impervious area (EIA) and concentrated surface flows on impervious surfaces by reducing or eliminating hardened conveyance structures (pipes or curbs and gutters).
- Infiltrate and slowly convey storm flows in roadside bioretention cells and swales, and through permeable paving and aggregate storage systems under the pavement.

- Design the road network to minimize site disturbance, avoid sensitive areas, and reduce fragmentation of landscape.
- Create connected street patterns and utilize open space areas to promote walking, biking and access to transit and services.
- Provide efficient fire and safety vehicle access.

Local access and small-collector road design is influenced at the individual parcel and subdivision scale and is the focus of this section. Road design is site specific; accordingly, this section does not recommended specific road designs. Instead, the strengths and weaknesses of different road layouts are examined in the context of LID to assist designers in the process of providing adequate transportation systems while reducing impervious surface coverage.

3.1.1 Medium to High Density Subdivision and Planned Community

Road layout

The Urban Land Institute (ULI), Institute of Transportation Engineers (ITE), National Association of Home Builders, and American Society of Civil Engineers state in a 2001 collaborative publication that: “The movement of vehicles is only one of a residential street’s many functions. A residential street is also part of its neighborhood and provides a visual setting for the homes as well as a meeting place for residents.” Additionally, ULI recommends that the land area devoted to streets should be minimized (National Association of Home Builders [NAHB], American Society of Civil Engineers, Institute of Transportation Engineers, and Urban Land Institute, 2001). These recommendations are derived primarily from a livability and safety perspective; however, the guidelines also integrate well with the low impact development design approach.

Designs for residential roads generally fall into three categories: grid, curvilinear and hybrids. Figure 3.1 illustrates the grid and curvilinear road layouts and Table 3.1 summarizes the strengths and weaknesses of the grid and curvilinear approaches.

Table 3.1 Strengths and weaknesses of the grid and curvilinear approaches.

Road Pattern	Impervious Coverage	Site Disturbance	*Biking, Walking, Transit	Safety	Auto Efficiency
Grid	27-36% (Center for Housing Innovation, 2000 and CMHC, 2002)	less adaptive to site features and topography	promotes by more direct access to services and transit	may decrease by increasing traffic throughout residential area	more efficient—disperses traffic through multiple access points
Curvilinear	15-29% (Center for Housing Innovation, 2000 and CMHC, 2002)	more adaptive for avoiding natural features, and reducing cut and fill	generally discourages through longer, more confusing, and less connected system	may increase by reducing traffic in dead end streets	less efficient—concentrates traffic through fewer access points and intersections

** Note: biking, walking and transit are included for livability issues and to reduce auto trips and associated pollutant contribution to receiving waters.*

Figure 3.1

Top: Typical grid road layout with alleys.

Lower: Typical curvilinear road layout with cul-de-sacs.

Graphic by AHBL Engineering

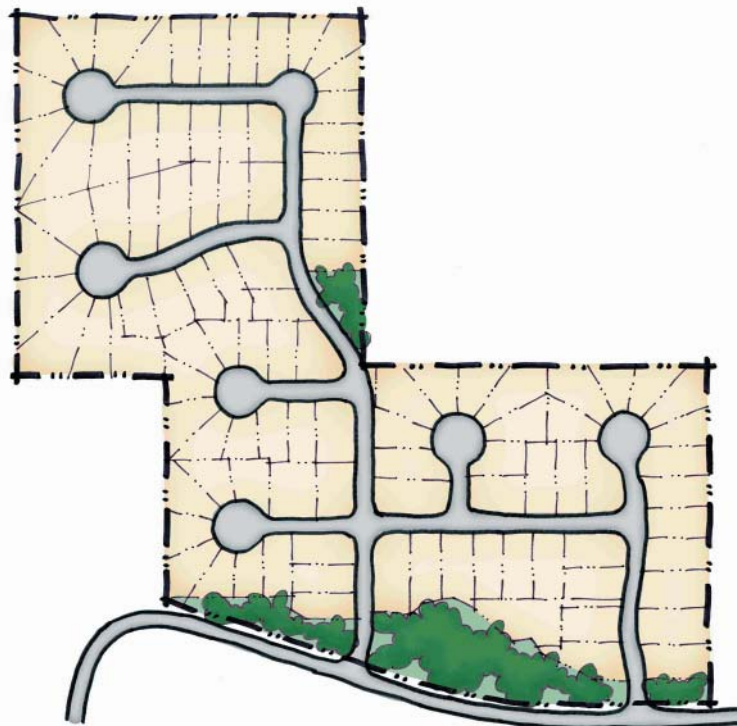


Figure 3.2 Hybrid, or open space, road layout.

Graphic by AHBL Engineering



The grid and curvilinear systems both have advantages and disadvantages. However, grid street patterns with alleys have one large drawback in the LID context: grids typically require 20 to 30 percent more total street length than curvilinear patterns (CWP, 1998 and Table 3.1). Recently, planners have integrated the two prevalent models to incorporate the strengths of both. These street networks have several names including open space, hybrid, and headwater street plans (Figure 3.2).

The following are strategies used to create road layouts in medium to higher density low impact residential developments that provide effective transportation networks and minimize impervious surface coverage:

- Cluster homes to reduce overall development envelope and road length (Schueler, 1995).
- Narrow lot frontages to reduce overall road length per home (see Figure 3.2) (Schueler, 1995).
- For grid or modified grid layouts, lengthen street blocks to reduce the number of cross streets and overall road network per home, and provide mid-block pedestrian and bike paths to reduce distances to access transit and other services (Center for Housing Innovation [CHI], 2000).
- Where cul-de-sacs are used, provide pedestrian paths to connect the end of the street with other pathways, transit or open space (Ewing, 1996).
- Provide paths in open space areas to increase connection and access for pedestrians and bicyclists (Ewing, 1996).
- Create pedestrian routes to neighborhood destinations that are direct, safe and aesthetically pleasing (CHI, 2000).

- Reduce road widths and turn around area coverage (see road widths, parking and driveway sections).
- Reduce front yard set backs to reduce driveway length.
- Minimize residential access road right-of-way to only accommodate needed infrastructure next to road (residential access roads are rarely widened) (Schueler, 1995).
- Eliminate, or reduce to an absolute minimum, all stream crossings.

The road and pedestrian pathway networks in figures 3.3 and 3.4 illustrate multifunctional road layout designs.

Figure 3.3 Loop road design.

Graphic by AHBL Engineering

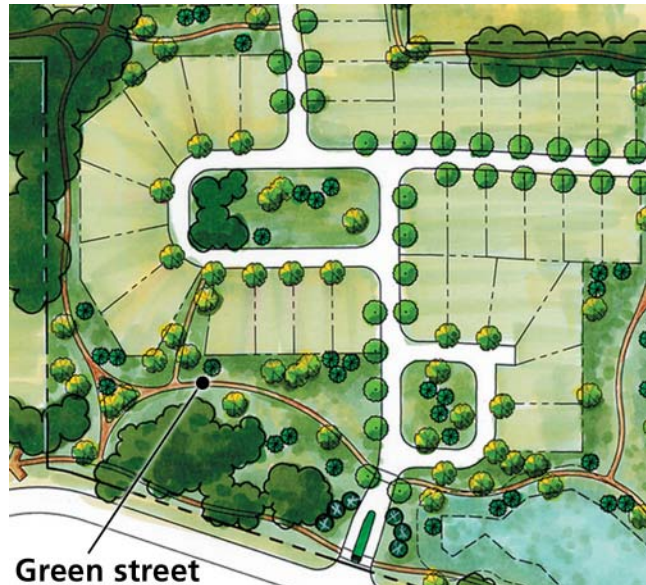
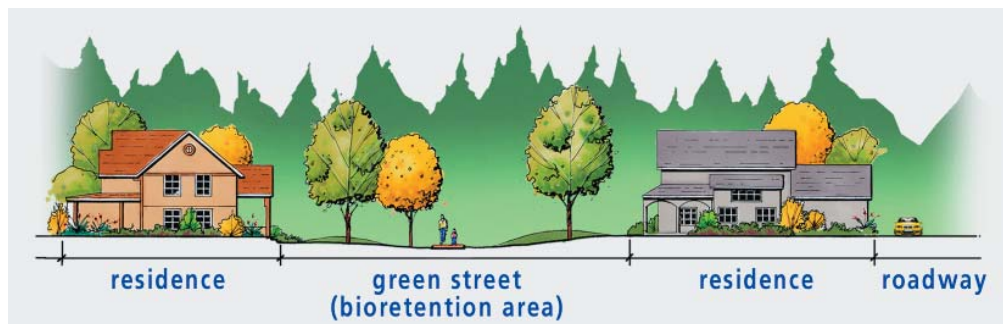


Figure 3.4 Green street section.

Graphic by AHBL Engineering



The loop road design:

- Minimizes impervious road coverage per dwelling unit.
- Provides adequate turning radius for fire and safety vehicles.
- Provides through traffic flow with two points of access.
- Provides a large bioretention area in the center of the loop and a visual landscape break for homes facing the road.

The open space pathways between homes (green streets):

- Provide a connected pedestrian system that takes advantage of open space amenities.

- Provide additional stormwater conveyance and infiltration for infrequent, large storm events.

The Sherbourne project in figures 3.5 and 3.6 is designed with one access to the development; however, ample traffic flow through the subdivision is provided by the loop and along home frontages, allowing for easier movement of fire and safety vehicles. Open space in the center of the loop provides stormwater storage, a visual landscape break for homes facing the road, and a creative example of integrating a regulatory requirement with a site amenity.

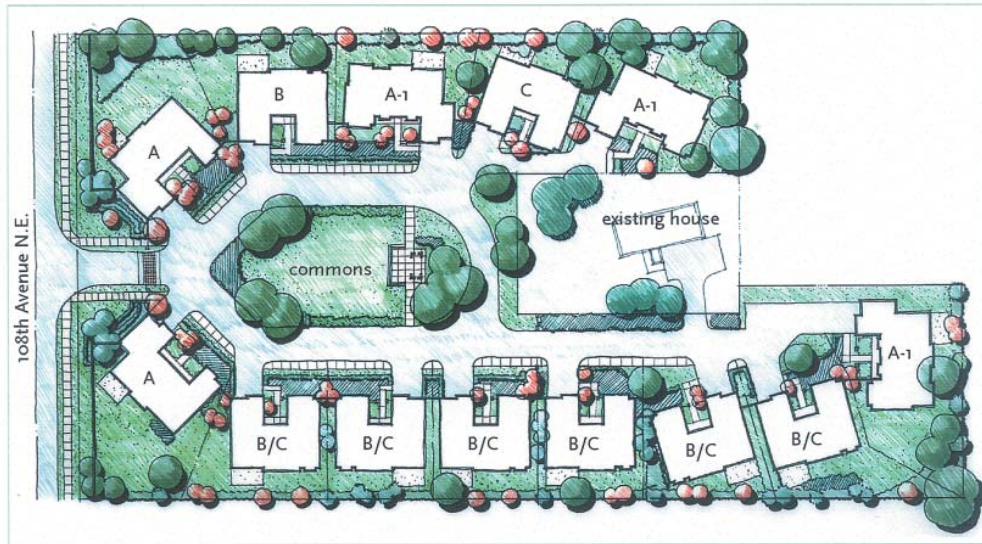


Figure 3.5 Sherbourne plan view.

Graphic courtesy of Mithun



Figure 3.6 Combined commons and stormwater facility at Sherbourne.

Photo by Colleen Owen

Road width

Residential road widths and associated impervious surface have, for various reasons, increased by over 50 percent since the mid-1900's (Schueler, 1995). Road geometry, including road widths, are derived primarily from two sources: American Association of State Highway Transportation Officials (AASHTO) and ITE (Schueler, 1995). A standardized guideline for residential roads that responds to general safety, traffic flow, emergency access, and parking needs is often adopted from these sources to

fit various development scenarios. For example, AASHTO recommends 26-foot pavement widths and 50-foot right of way for residential roads across various density and traffic load demands. Additionally, many communities continue to equate wider streets with better and safer streets. Studies indicate, however, that residential accidents may increase exponentially as the street gets wider, and narrower roads that reduce traffic speeds are safer (CHI, 2000; NAHB et al., 2001; and Schueler, 1995).

Total and effective impervious area can be significantly reduced by determining specific traffic, parking, and emergency vehicle access needs and designing for the narrowest width capable of meeting those requirements. Examples of narrow street widths tailored to traffic need from different U.S. locations and from ULI are provided in Table 3.2. Reducing the street width from 26 to 20 feet reduces TIA by 30 percent. In the road network represented in Figure 3.2, the 30 percent reduction represents a storm flow reduction from 15,600 cubic feet to 12,000 cubic feet for a 2 inch 24-hour storm.

Table 3.2 Examples of narrow street widths from various jurisdictions.

Location or Source	Street Type	Width	Volume (ADT*)	Parking
Buck's County, PA	local access	18 ft	200	none
Buck's County, PA	residential collector	20 ft	200-1,000	none
Portland, OR	queuing	26 ft	not reported	both sides
ULI	shared driveway (5-6 homes)	16 ft	not reported	not reported
ULI	local	18 ft	not reported	one side only
ULI	local	22-26 ft	not reported	both sides
ULI	alley	12 ft	not reported	none
City of Seattle	local access	14 ft	125 (from traffic counts)	none
City of Seattle	local access	20 ft	250 (from traffic counts)	one side
City of Olympia	local access (2-way)	18 ft	0-500	none
City of Olympia	local access (queuing)	18 ft	0-500	one side alternating
City of Olympia	neighborhood collector	25 ft	500-3000	one side alternating

* ADT: Average daily traffic

Turnarounds

Dead end streets with excessive turn around area (particularly cul-de-sacs) can needlessly increase impervious area. In general, dead end or cul-de-sac streets should be discouraged; however, a number of alternatives are available where topography, soils or other site specific conditions suggest this road design. Thirty-foot radius turnarounds are adequate for low volume residential roads servicing primarily passenger vehicles (AASHTO, 2001 and NAHB et al., 2001). A 40-foot radius with a landscaped center will accommodate most service and safety vehicle needs when a minimum 20-foot internal turning radius is maintained (Schueler, 1995). The turning area in a cul-de-sac can be enhanced by slightly enlarging the rear width of the radius. A hammerhead turnaround requires vehicles to make a backing maneuver, but this

inconvenience can be justified for low volume residential roads servicing 10 or fewer homes (NAHB et al., 2001). A 10-foot reduction in radius can reduce impervious coverage by 44 percent and the hammerhead configuration generates approximately 76 percent less impervious surface than the 40-foot cul-de-sac. Four turnaround options and associated impervious surface coverage are presented in Figure 3.7.

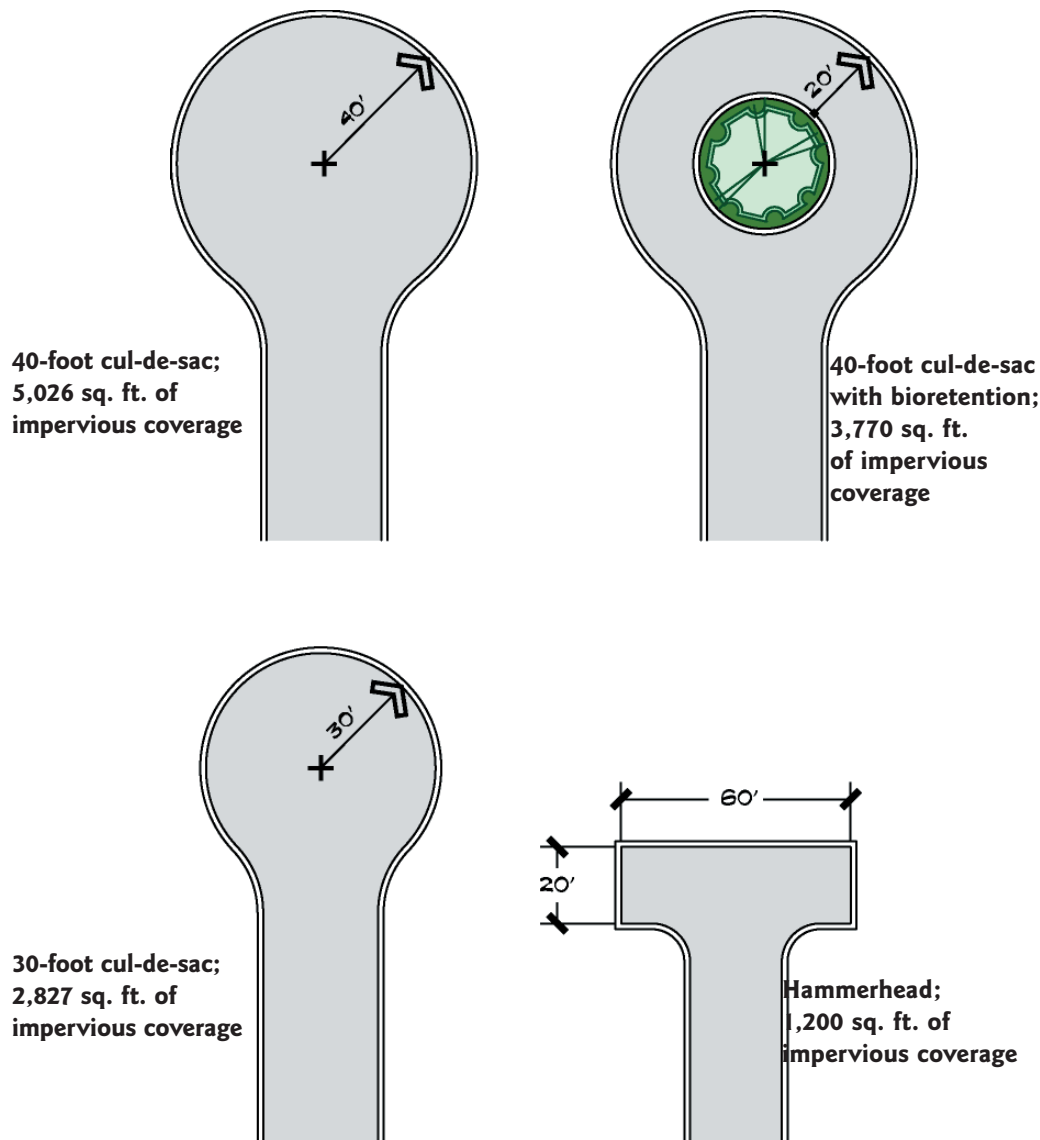


Figure 3.7 Turnaround areas and associated impervious coverage.

Graphic by AHBL Engineering

Islands in cul-de-sacs should be designed as bioretention or detention facilities. Either a flat concrete reinforcing strip or curb-cuts can be utilized to allow water into the facility (see Section 6.3: Permeable Paving for details).

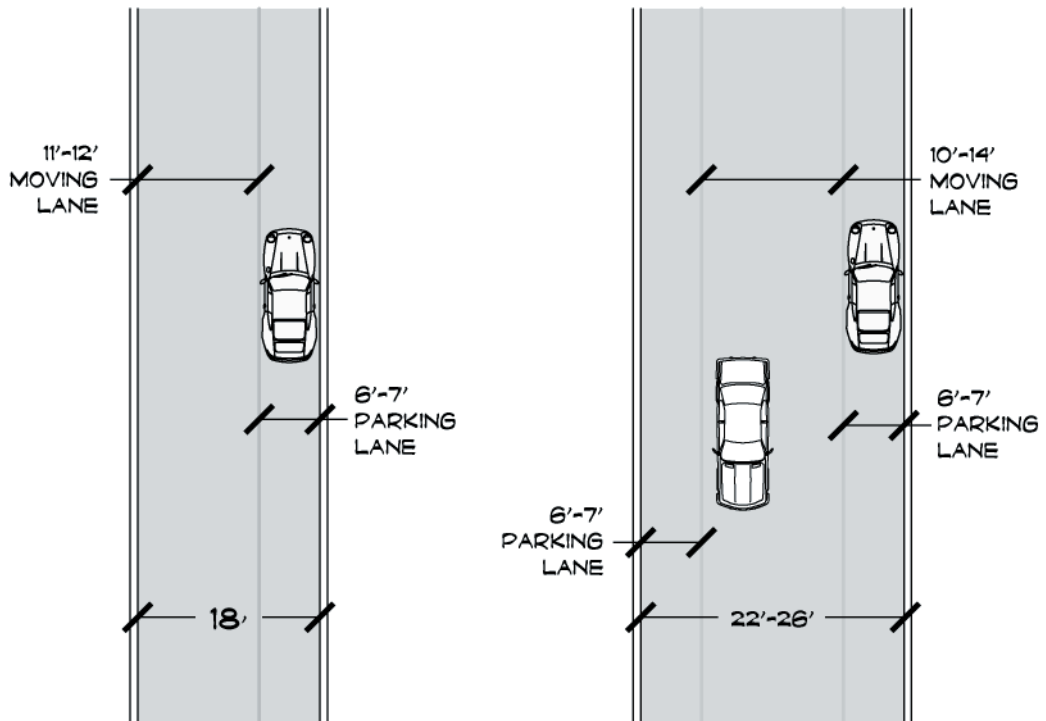
The loop road configuration is an alternative to the dead end street and provides multiple access points for emergency vehicles and residents (see figures 3.3 and 3.5). For similar impervious surface coverage, the loop road has the additional advantage of increasing available storm flow storage within the loop compared to the cul-de-sac design.

Parking

Many communities require 2 to 2.5 parking spaces per dwelling. Driveways and garages can accommodate this need in most cases, and providing curb side parking on both sides of the street and two travel lanes (i.e., the 36-foot wide local residential street) creates excess impervious surface. Parking needs and traffic movement can be met on narrowed roads where one or two on-street parking lanes serve as a traffic lane (queuing street) (CWP, 1998). Figure 3.8 provides two examples of queuing streets for local residential streets.

Figure 3.8

*Left: 18-ft street with parking on one side.
Right: 22 to 26-ft street with parking on both sides.
(Adapted from National Association of Home Builders et al., 2001)*



In higher density residential neighborhoods with narrow roads and where no on-street parking is allowed, pullout parking can be utilized. Pullouts (often designed in clusters of 2 to 4 stalls) should be strategically distributed throughout the area to minimize walking distances to residences. Depending on the street design, the parking areas may be more easily isolated and the impervious surface rendered ineffective by slightly sloping the pavement to adjacent bioretention swales or bioretention cells (Figure 3.9).

All or part of pullout parking areas, queuing lanes or dedicated on-street parking lanes can be designed using permeable paving (see Figure 3.10 for an example design). Permeable asphalt, concrete, pavers, and gravel pave systems can support the load requirements for residential use, reduce or eliminate storm flows from the surface, and may be more readily acceptable for use on lower-load parking areas by jurisdictions hesitant to use permeable systems in the travel way. Particular design and management strategies for subgrade preparation and sediment control must be implemented where pullout parking or queuing lanes receive storm flows from adjacent impervious areas (see Section 6.3: Permeable Paving for details).

Traffic calming strategies

Several types of traffic calming strategies are used on residential roadways to reduce vehicle speeds and increase safety. These design features also offer an opportunity for storm flow infiltration and/or slow conveyance to additional LID facilities downstream (figures 3.11 and 3.12).



Figure 3.9 Pullout parking adjacent to a 14-foot residential access road, Seattle.

Photo by Colleen Owen

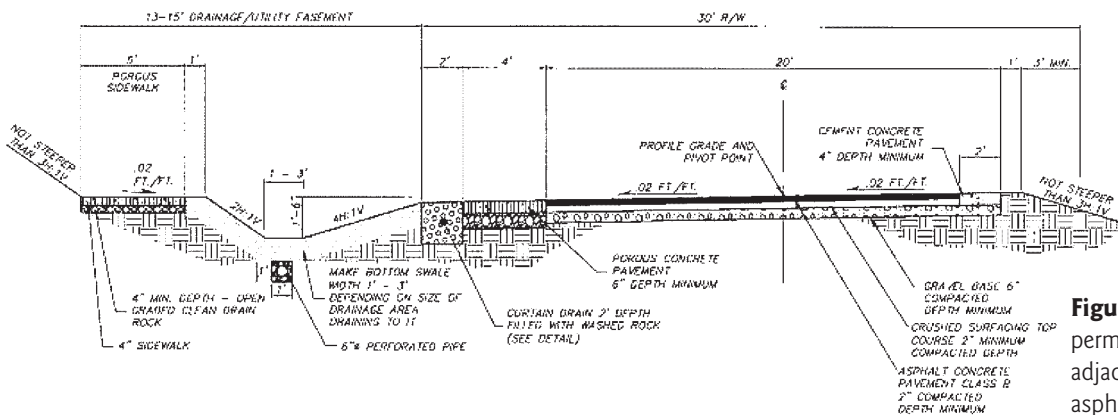


Figure 3.10 Four-foot permeable paving section adjacent to conventional asphalt roadway.

Courtesy of Pierce County Department of Public Works and Utilities

Alleys

Alleys should be the minimum width required for service vehicles, constructed of permeable paving materials, and allow any surface flows to disperse and infiltrate to adjacent bioretention swales, shoulders or yards (Figure 3.13). Strategies to reduce TIA associated with alleys include:

Maximum alley width should be 10 to 12 feet with 14- to 16-foot right-of-ways respectively.

Several permeable paving materials are applicable for low speeds and high service vehicle weights typically found in alleys including:

- Gravel pave systems.
- Permeable concrete.
- Permeable pavers.
- Systems integrating multiple permeable paving materials.

See Section 6.3: Permeable Paving for details.

Figure 3.11 Combination stormwater management and traffic calming. (Note: These areas are slightly lower than road surface.)

Graphic by AHBL Engineering

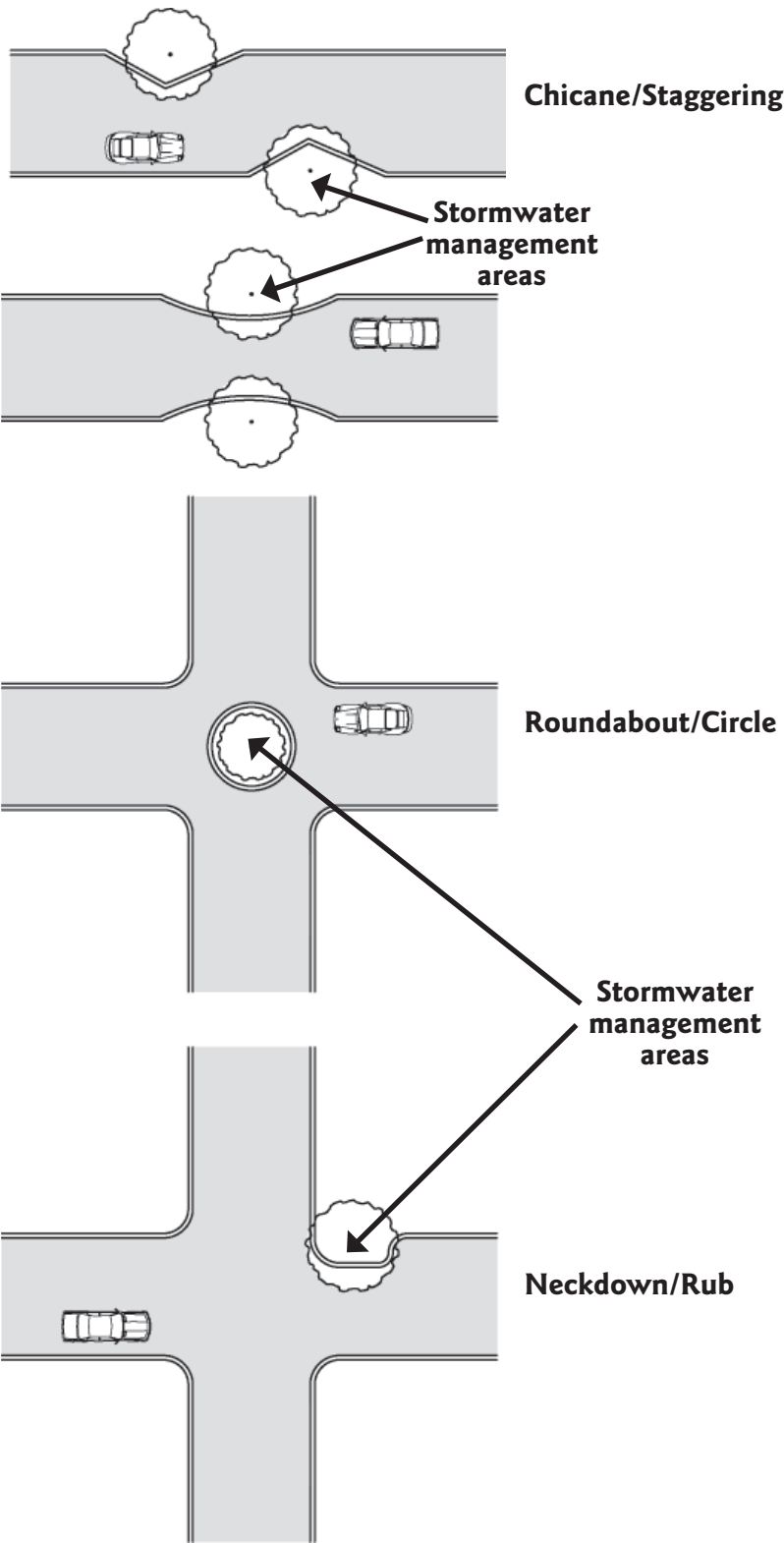




Figure 3.12 Siskiyou project in Portland, Oregon uses traffic calming designs to manage stormwater. Note curb cuts that allow stormwater to enter bioretention area in narrow section of road.

Photo by Erica Guttman

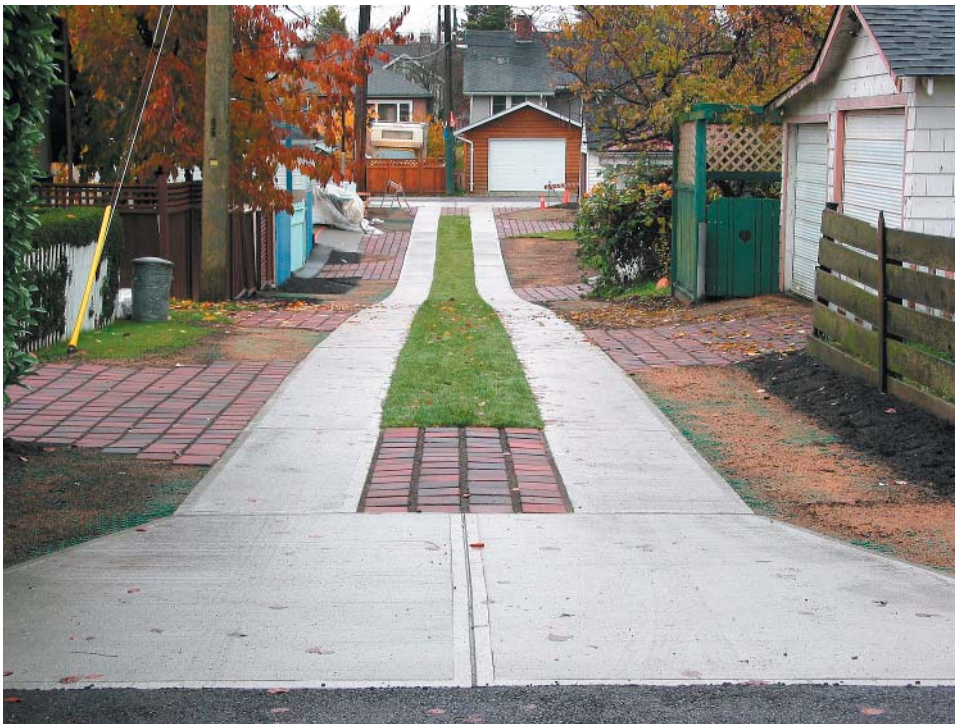


Figure 3.13 Vancouver, BC Country Lane alley uses a combination of concrete wheel strips, permeable pavers, reinforced plastic grid with grass, and under-drains to attenuate storm flows and create an aesthetic design objective.

Photo by Curtis Hinman

Driveways

As much as 20 percent of the impervious cover in a residential subdivision can be attributed to driveways (CWP, 1998). Several techniques can be used to reduce impervious coverage associated with driveways including:

- Shared driveways provide access to several homes and may not have to be designed as wide as local residential roads (Figure 3.14). Recommendations range from 9 to 16 feet in width serving 3 to 6 homes (NAHB et al., 2001 and Prince George's County, Maryland, 2000). A hammerhead or other configuration that generates minimal impervious surface may be necessary for turnaround and parking area.
- Minimize front yard setbacks to reduce driveway length.
- Reduce minimum driveway width from 20 (common standard) to 18 feet. Driveways can be reduced further to 10 feet with a bulb-out at the garage.

Figure 3.14 Issaquah Highlands shared driveway.
Photo by Curtis Hinman



- Use permeable paving materials and aggregate storage under wearing surface.
- Limit impervious surface to two tracks with remainder in reinforced grass or other pervious surface (California strips).
- Direct surface flow from driveways to compost-amended soils, bioretention areas or other dispersion and infiltration areas (see Section 6.2: Amending Construction Site Soils and Section 6.1: Bioretention Areas for details).

Sidewalks

Many jurisdictions require sidewalks on both sides of residential roads for safety and perceived consumer demand. Studies indicate that pedestrian accident rates are similar in areas with sidewalks on one or both sides of the street (CWP, 1998). Limited assessments suggest that there is no appreciable market difference between homes with sidewalks on the same side of the street and homes with sidewalks on the opposite side of the road (CWP, 1998). The Americans with Disabilities Act (ADA) does not require sidewalks on both sides, but rather at least one accessible route from public streets (WAC 51-40-1100, 2003). Impervious surface coverage generated by sidewalks can be reduced using the following strategies:

- Reduce sidewalk to a minimum of 44 inches (ADA recommended minimum) or 48 inches (AASHTO, 2001 and NAHB et al., 2001 recommended minimum).
- For low speed local access roads eliminate sidewalks or provide sidewalks on one side of the road. A walking and biking lane, delineated by a paint stripe, can be included along the roadway edge.
- Design a bioretention swale or bioretention cell between the sidewalk and the street to provide a visual break and increase the distance of the sidewalk from the road for safety (NAHB et al., 2001).
- Install sidewalks at a two percent slope to direct storm flow to bioretention swales or bioretention cells—do not direct sidewalk water to curb and gutter or other hardened roadside conveyance structures.
- Use permeable paving material to infiltrate or increase time of concentration of storm flows (see Section 6.3: Permeable Paving for details).



Figure 3.15 Permeable concrete walkway and parking area on Whidbey Island.

Courtesy of Greg McKinnon

3.1.2 Low Density/Large Lots

Dispersion

Low density or large lot development offer increased opportunities or land area to integrate LID dispersion, storage, and infiltration strategies. The greater distances between residences can, however, increase the overall road network and total impervious coverage per dwelling (Schueler, 1995). Preserving or restoring native soils and vegetation along low density road networks and driveways, and dispersing storm flows to those areas offers a low cost and effective LID strategy. Designs for dispersion should minimize surface flow velocities and not concentrate storm flows.

The strategies for road, driveway, parking and other LID designs appropriate in medium to high density settings (see Section 3.1.1) can be applied in large lot settings as well.

Driveways

Shared driveways are applicable in large lot as well as higher density settings. Figure 3.16 is a large lot conservation design for protecting open space and uses shared driveways to access homes.



Figure 3.16 Large lot cluster design with shared driveway.

Graphic by AHBL Engineering

3.1.3 Commercial

Parking

Parking lots and roof tops are the largest contributors to impervious surface coverage in commercial areas. Typical parking stall dimensions are approximately 9 to 9.5 feet by 18.5 to 19 feet, totaling 166.5 and 180.5 square feet respectively (Schueler, 1995 and City of Olympia, 1995). Considering the total space associated with each stall including overhangs, access isle, curbs, and median islands, a parking lot can require up to 400-square feet per vehicle or approximately one acre per 100 cars (CHI, 2000). The large effective impervious coverage associated with parking areas accumulates high pollutant loads from atmospheric deposition and vehicle use (auto pollutant contributions can be particularly heavy during stopping and starting a vehicle). As a result, commercial parking lots can produce greater levels of petroleum hydrocarbons and trace metals (cadmium, copper, zinc, lead) than many other urban land uses (Schueler, 1995 and Bannerman et al., 1993).

Many jurisdictions specify parking demand ratios as a minimum number of spaces that must be provided for the development type, number of employees, gross floor area or other parking need indicator. While parking infrastructure is a significant expense for commercial development, providing excess parking is often perceived as necessary to attract (or not discourage) customers. As a result, minimum standards are often exceeded in various regions of the U.S. by 30 to 50 percent (Schueler, 1995). In a local study, the city of Olympia found that 70 percent of all parking lots surveyed had at least 25 percent additional capacity during normal and peak hours (City of Olympia, 1995). The same study concluded that a 20 percent reduction in parking stalls was feasible without significantly impacting business activity.

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Capping parking demand ratios to reflect actual need is the most effective of several methods used to reduce impervious coverage in parking areas. In a commercial parking area selected in the Olympia study (526 stalls), a 20 percent reduction (105 stalls) would reduce surface flows by approximately 4,000 cubic feet for a typical two-year event (City of Olympia, 1995).

To reduce impervious coverage, storm flows, and pollutant loads from commercial parking areas, several LID strategies can be employed including:

- Assess parking demand ratios to determine if ratios are within national or, if available, actual local ranges (Schueler, 1995).
- Establish minimum and maximum or median parking demand ratios and allow additional spaces above the maximum ratio only if parking studies indicate a need for added capacity.
- Dedicate 20 to 30 percent of parking to compact spaces (typically 7.5 by 15 feet).
- Use a diagonal parking stall configuration with a single lane between stalls (reduces width of parking isle from 24 to 18 feet and overall lot coverage by 5 to 10 percent) (Schueler, 1995).
- Where density and land value warrant, or where necessary to reduce TIA below a maximum allowed by land use plans, construct underground, under building or multi-story parking structures.
- Use permeable paving materials for the entire parking area or, at a minimum, for spillover parking that is used primarily for peak demand periods (Figure 3.17).

- Integrate bioretention into parking lot islands or planter strips distributed throughout the parking area to infiltrate, store, and/or slowly convey storm flows to additional facilities.
- Encourage cooperative parking agreements to coordinate use of adjacent or nearby parking areas that serve land uses with non-competing hours of operation—for example a cooperative agreement between a church and an office or retail store (City of Olympia, 1995).

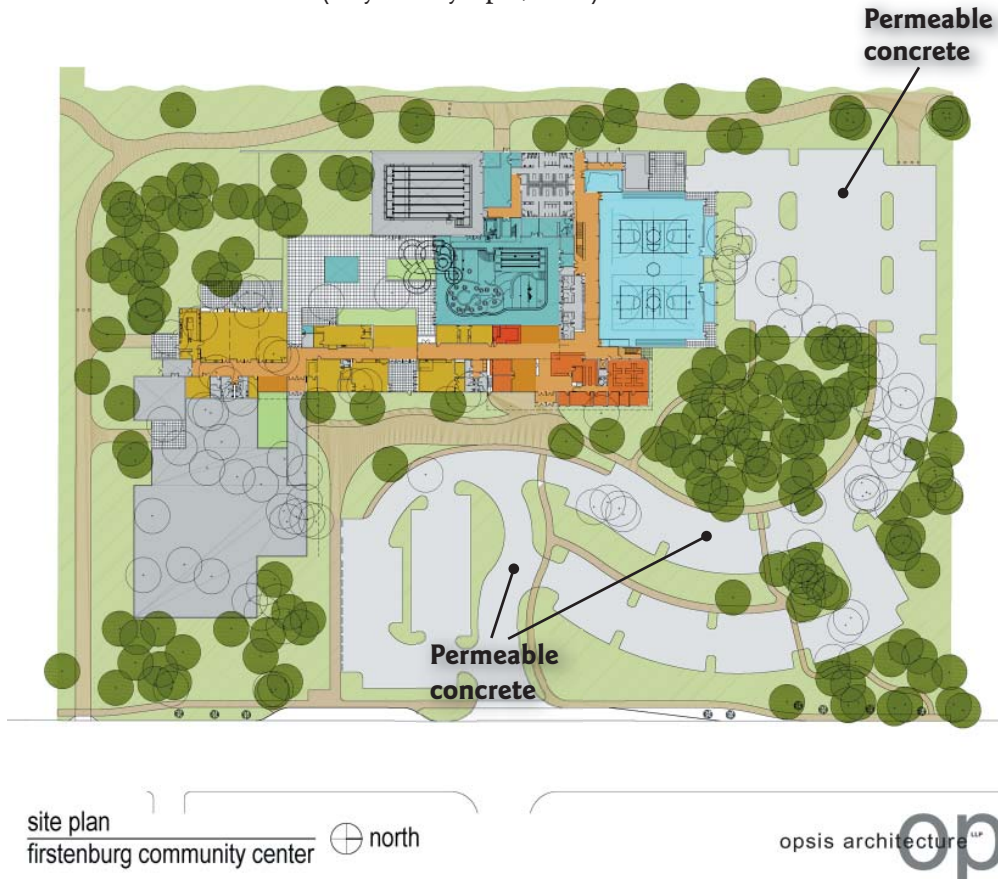


Figure 3.17 Firtenburg project in Vancouver, Washington includes 100,000 square feet of permeable concrete.
Courtesy of 2020 Engineering

3.2 Road Crossings

Numerous studies have correlated increased total impervious area with declining stream and wetland conditions (Azous and Horner, 2001; Booth et al., 2002; May et al., 1997). Recent research in the Puget Sound region suggests that the number of stream crossings per stream length may be a relatively stronger indicator of stream health (expressed through Benthic Index of Biotic Integrity) than TIA (Avolio, 2003). In general, crossings place significant stress on stream ecological health by concentrating and directing storm flows and contaminants to receiving waters through associated outfall pipes, fragmenting riparian buffers, altering hydraulics, and disrupting in-channel processes such as meander migration and wood recruitment (Avolio, 2003 and May, 1997). Culvert and bridge design that place supporting structures in the floodplain or active channel confine stream flows. The confined flow often increases bank and bed erosion resulting in channel enlargement downstream of the structure (Avolio, 2003). Bank armoring associated with crossings further disrupts hydraulics and channel processes and can increase the impacts of all crossing types including less damaging bridge designs (Avolio, 2003).

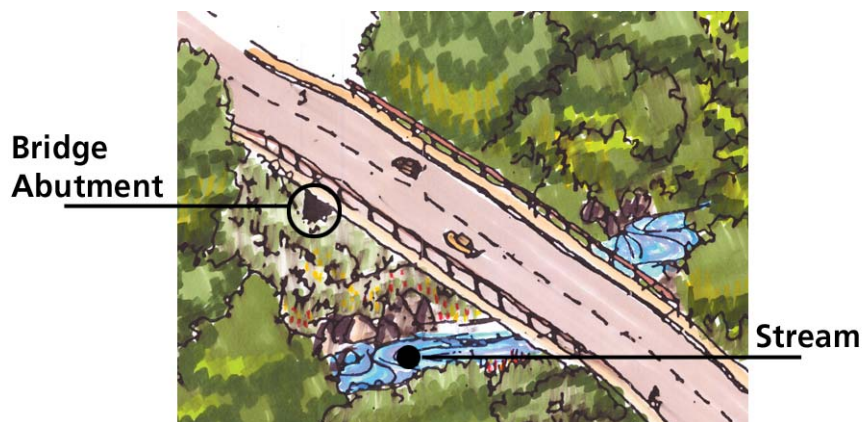
Road crossings place significant stress on stream ecological health by directing concentrated storm flows and contaminants to receiving waters, fragmenting riparian buffers, altering hydraulics, and disrupting in-channel processes.

Improperly designed crossings using culverts can also inhibit or completely block fish passage. Design considerations for minimizing road crossing impacts include:

- Eliminate, or reduce to an absolute minimum, all stream crossings.
- Where stream crossings are unavoidable, bridges are preferable to culverts.
- Locate bridge piers or abutments outside of the active channel or channel migration zone.
- If culverts are utilized, install slab, arch or box type culverts, preferably using bottomless designs that more closely mimic stream bottom habitat.
- Utilize the widest possible culvert design to reduce channel confinement.
- Minimize stream bank armoring and establish native riparian vegetation and large woody debris to enhance bank stability and diffuse increased stream power created by road crossing structures. (Note: consult a qualified fluvial geomorphologist and/or hydrologist for recommendations.)
- All crossings should be designed to pass the 100-year flood event.
- Cross at approximately 90 degrees to the channel to minimize disturbance.
- Do not discharge storm flows directly from impervious surfaces associated with road crossing directly to the stream—disperse and infiltrate stormwater or detain and treat flows.

Figure 3.18 Minimal impact stream crossing. Locate abutments outside of active channel or channel migration zone. Cross at approximately 90° to channel to minimize shading and other disturbances.

Courtesy of Portland Metro Green Streets Program



3.3 Street Trees

Trees can be used as a stormwater management tool in addition to providing more commonly recognized benefits such as energy conservation, air quality improvement, and aesthetic enhancement. Tree surfaces (foliage, bark, and branches) intercept, evaporate, store or convey precipitation to the soil before it reaches surrounding impervious surfaces. In bioretention cells or swales, tree roots build soil structure that enhances infiltration capacity and reduces erosion (Metro, 2003).

Appropriate placement and selection of tree species is important to achieve desired benefits and reduce potential problems such as pavement damage by surface roots and poor growth performance. When selecting species, consider the following site characteristics:

- Available growing space.
- Type of soil and availability of water.
- Overhead wires.
- Vehicle and pedestrian sight lines.
- Proximity to paved areas and underground structures.

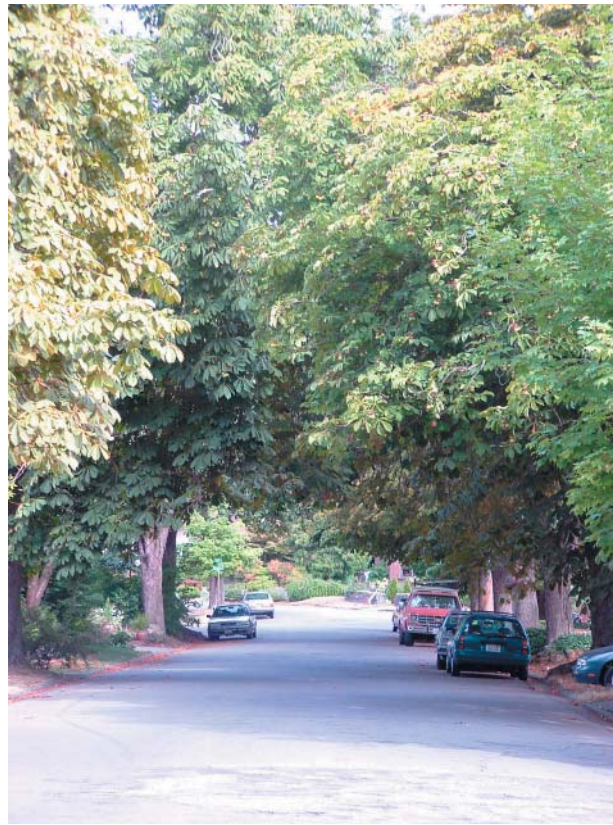


Figure 3.19 Street trees—Queen Anne neighborhood, Seattle.

Photo by Colleen Owen

- Proximity to neighbors, buildings, and other vegetation.
- Prevailing wind direction and sun exposure.
- Additional functions desired, such as shade, aesthetics, windbreak, privacy screening, etc.

Local jurisdictions often have specific guidelines for the types and location of trees planted along public streets or rights-of-way. The extent and growth pattern of the root structure must be considered when trees are planted in bioretention areas or other stormwater facilities with under-drain structures or near paved areas such as driveways, sidewalks or streets. Other important tree characteristics to consider when making a selection include:

- Longevity or life-span (ideally a street tree will be “long-lived”, meaning it has a life span of 100 years or more. However, the longevity of a tree will need to be balanced with other selection priorities).
- Tolerance for urban pollutants.
- Growth rate.
- Tolerance to drought, seasonally saturated soils, and poor soils.
- Canopy spread and density (trees that provide a closed street canopy maximize interception and evapotranspiration).
- Foliage texture and persistence.

Appendix 1 lists the growth pattern and appropriate site characteristics for a variety of trees appropriate for street, parking lot, residential yard, and bioretention applications.

3.4 Lot Layout

Typical residential development determines lot size by dividing the total plat acreage, minus the roads and regulated sensitive areas, by the number of lots allowed under the applicable zoning. Most, if not all, of the site is cleared and graded. In contrast, LID projects employ clustering and other planning strategies to minimize site disturbance, maximize protection of native soil and vegetation, and permanently set aside the open tracts for multiple objectives including stormwater management. Four general objectives should guide the placement and orientation of lots for LID projects:

- Minimize site disturbance.
- Strategically locate lots for dispersing stormwater to open space areas.
- Orient lots and buildings to maximize opportunities for on-lot infiltration or open conveyance through bioretention swales or cells to downstream LID facilities.
- Locate lots adjacent to, or with views of, open space to improve aesthetics and privacy.

The following examines three prevalent development strategies applied in a low impact development context—medium to high density cluster, rural cluster, and large lot development.

3.4.1 Medium to High Density Cluster (4 or More Dwelling Units Per Acre)

Clustering is a type of development where buildings are organized together into compact groupings that allow for portions of the development site to remain in open space (Maryland Office of Planning, 1994). In the U.S., the primary focus of cluster development has been to preserve natural and cultural features, provide recreation, preserve rural character, and produce more affordable housing (Schueler, 1995).

The LID cluster may include the above objectives; however, the primary purpose of the low impact development cluster is to minimize the development envelope, reduce impervious coverage, and maximize native soil and forest protection or restoration areas. Natural resource protection areas (the preferred strategy) are undisturbed conservation areas. Restoration areas (appropriate where land is or will be disturbed) can be enhanced through soil amendments and native planting to improve the hydrologic function of the site. Both can provide dispersion for overland flows generated in developed areas. Demonstration projects indicate that significant open space protection can still be achieved over conventional development projects designed with relatively small lot sizes when using cluster strategies (Figure 3.20).

Objectives for medium to high density clustering:

- Medium density (4 to 6 dwelling units per acre): reduce the development envelope in order to retain a minimum of 50 percent open space.
- High density (more than 6 dwelling units per acre): protect or restore to the greatest extent possible. Note: in medium to high density settings, reducing the development envelope and protecting native forest and soil areas will often require multifamily, cottage, condominium or mixed attached and detached single family homes.

Techniques to meet objectives for medium to high density clustering include:

- Minimize individual lot size (3,000 to 4,000 square-foot lots can support a medium sized home designed to occupy a compact building footprint).

Figure 3.20 Conventional small lot development compared to LID cluster design.

Graphic by AHBL Engineering

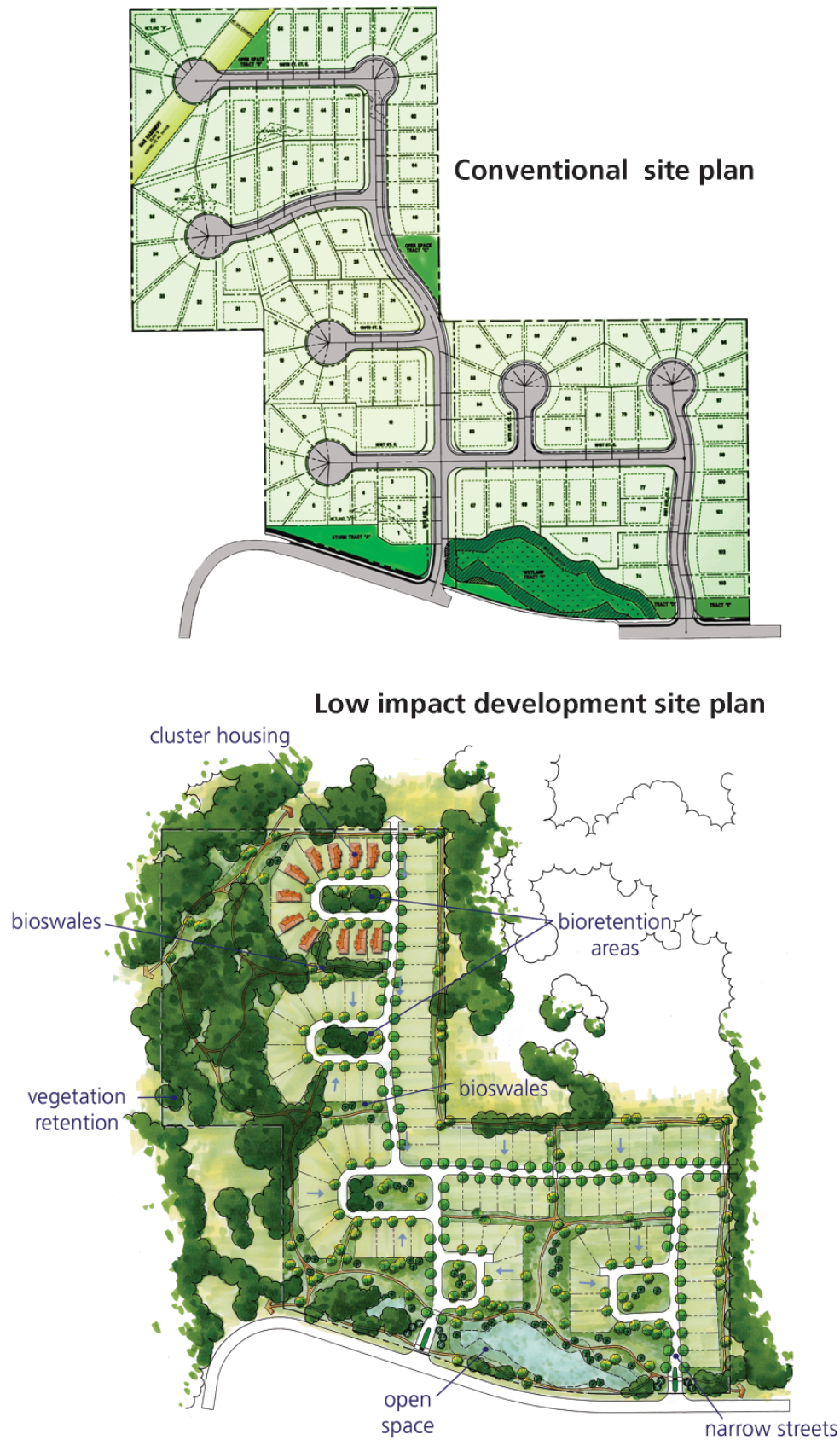


Figure 3.21 Example of medium- to high-density lot using low impact development practices.

Graphic by AHBL Engineering

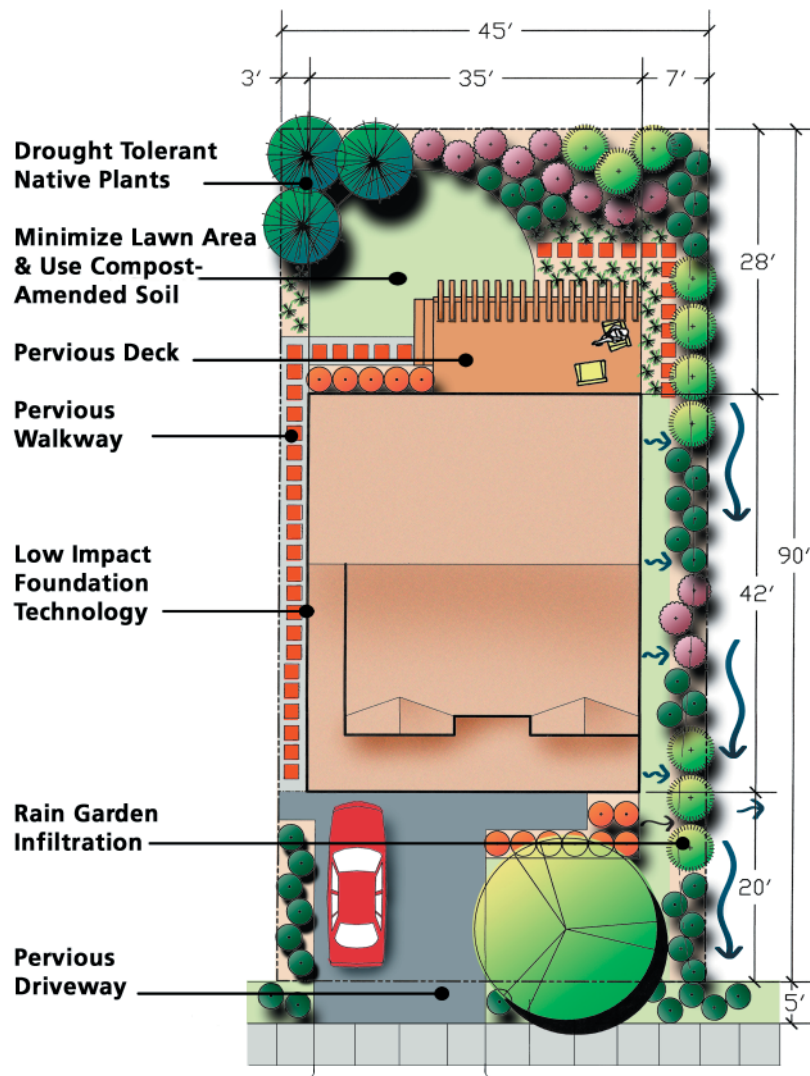


Figure 3.22 Zero lot line configuration.

Graphic by AHBL Engineering





Figure 3.23 Shared courtyard in a cottage development in Seattle.
Photo by Curtis Hinman



Figure 3.24 Cluster of homes designed with vegetated roofs in Berlin, Germany.
Photo courtesy of Patrick Carey

- Minimize setbacks. Examples of minimum setbacks include:
 - o 25-foot front yard.
 - o 3-foot side yard (minimum side yard set backs should allow for fire protection ladder access, and structures with narrow side yards should use fire resistant siding materials).
- Use zero lot line set back to increase side yard area (Figure 3.22).
- Use cottage designs for a highly compact development envelope.
- Amend disturbed soils to regain stormwater storage capacity (see Section 6.2: Amending Construction Site Soils).
- Drain rooftops to cisterns for non-potable reuse within the house or garden (see Section 6.6: Roof Rainwater Collection Systems).
- Utilize vegetated roof systems to evaporate and transpire stormwater (see Section 6.4: Vegetated Roofs).
- Lay out roads and lots to minimize grading to the greatest extent possible.
- Stormwater from lots not adjacent to forested/open space infiltration areas can be conveyed in swales or dispersed as low velocity (< 1fps) sheet flow to the infiltration areas.
- Orient lots to use shared driveways to access houses along common lot lines.
- To maximize privacy and livability within cluster developments, locate as many lots as possible adjacent to open space, orient lots to capture views of open space, and design bioretention swales and rain gardens as visual buffers.
- Set natural resource protection areas aside as a permanent tract or tracts of open space with clear management guidelines.

A little known, but effective, cluster strategy is Air Space Condominium design. In this design scenario (applicable for most single family residential development),

the property is not divided into separate lots. Instead, designated areas, or air space, that include the dwelling and some additional yard space (optional) are available for purchase with the remaining property held in common and managed by a homeowners association. The stormwater management practices are held within an easement for local jurisdiction access and require a long-term management agreement followed by the homeowners. The advantage of the condominium classification is increased design flexibility including:

- The entire road network can be considered as driveway reducing design standards for road widths, curb and gutter, etc.
- No minimum lot size.
- Reduced overall development envelope.

Note: fire and vehicle safety requirements must still be satisfied.

3.4.2 Rural Cluster and Large Lot Development

Substantial reduction of impervious surfaces can be realized through clustering large lot development. In a study comparing 100-lot subdivision designs, the Maryland Office of State Planning found a 30 percent reduction in impervious surface when lot size was reduced from a typical rural density of 1.4 to 0.25 acres. Additional road network and driveway lengths are the primary reasons for increased imperviousness associated with large lot development (Delaware Department of Natural Resources and Environmental Control and the Environmental Management Center of the Brandywine Conservancy, 1997). The increased storm flows from the additional road network required to serve rural cluster and large lot designs should be dispersed to bioretention swales, adjacent open space, and/or lawn areas amended with compost (figures 3.25 and 3.26).

Objectives for rural clustering and large lots:

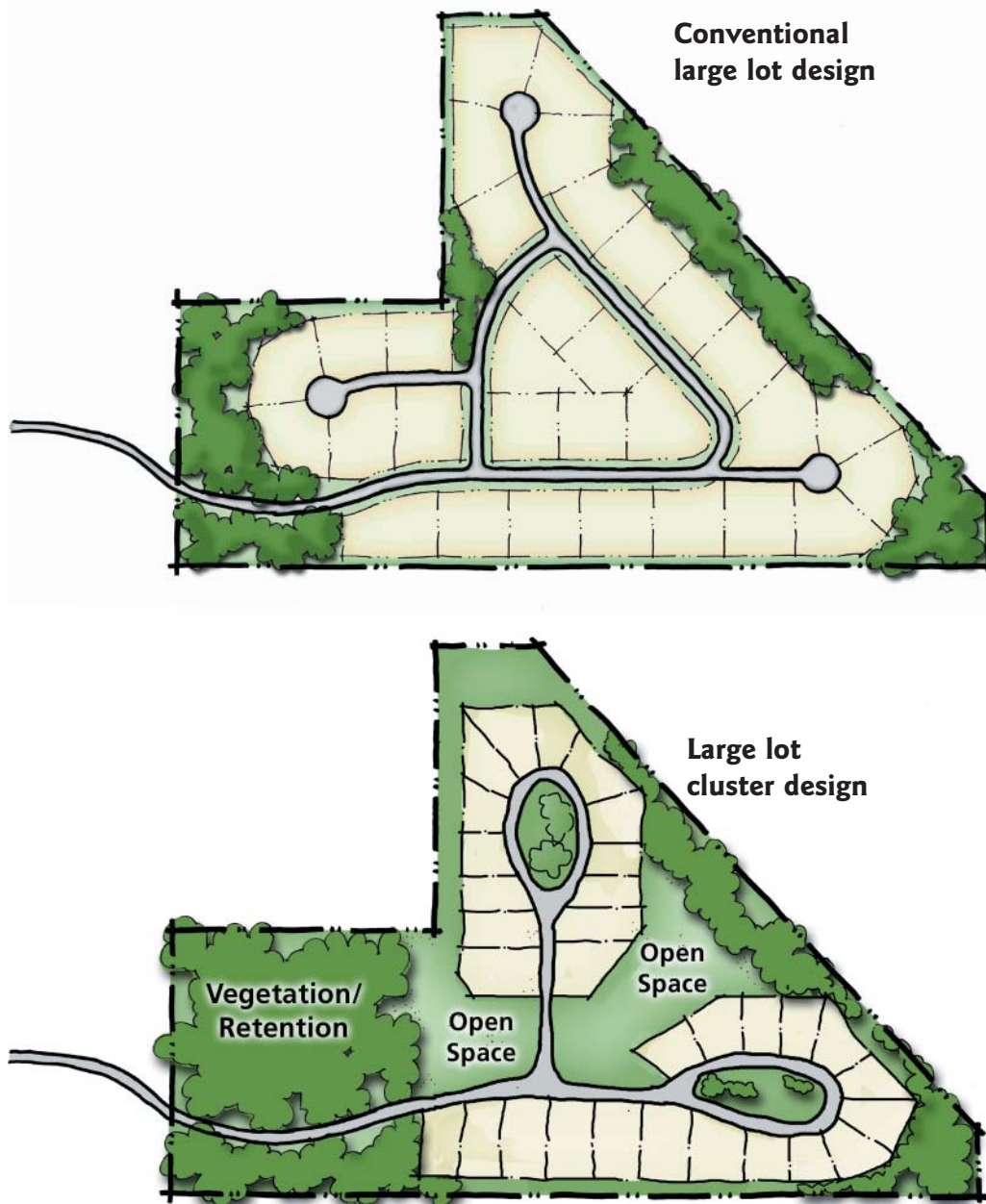
- Reduce the development envelope in order to retain a minimum of 65 percent of the site in native soil and vegetation.
- Reduce EIA to zero (fully disperse stormwater).

Medium to high density cluster guidelines can be used in large lot settings. The increased land area in the rural cluster and large lot scenarios offer additional opportunities including:

- Integrate bioretention and open bioretention swale systems into the landscaping to store, infiltrate, slowly convey, and/or disperse stormwater on the lot.
- Disperse road and driveway stormwater to adjacent open space and lawn areas (see Chapter 7: Flow Modeling Guidance for dispersion details).
- Maintain pre-development flow path lengths in natural drainage patterns.
- Preserve or enhance native vegetation and soil to disperse, store, and infiltrate stormwater.
- Disperse roof water across the yard and to open space areas or infiltrate roof water in infiltration trenches.
- Lots may be organized into cluster units separated by open space buffers as long as road networks and driveways are not increased significantly, and the open space tract is not fragmented.
- Place clusters on the site and use native vegetation to screen or buffer higher density clusters from adjacent rural land uses.

Figure 3.25 Conventional and large lot cluster designs.

Graphic by AHBL Engineering



3.5 Building Design

Impervious surface associated with roofs ranges from approximately 15 percent for single family residential, 17 percent for multifamily residential, and 26 percent for commercial development (City of Olympia, 1995). As densities increase for detached single-family residential development, opportunities for infiltrating roof stormwater decrease; however, other strategies to process this water can be applied.

Objectives for building design strategies are to disconnect roof stormwater from stormwater conveyance and pond systems (i.e., eliminate roofs as effective impervious surface), and reduce site disturbance from the building footprint. Strategies for minimizing storm flows and disturbance include:

- Reduce building footprint. Designing taller structures can reduce building footprints and associated impervious surface by one-half or more in comparison to a single story configuration. Proposals to construct taller buildings can also

Figure 3.26 Large lot LID design example.

Graphic by AHBL Engineering



present specific fire, safety, and health issues that may need to be addressed. For example, any residence over two stories requires a fire escape and a sprinkler system. These additional costs may be partially reduced by a reduction in stormwater conveyance and pond systems and stormwater utility fees.

- Orient the long axis of the building along topographic contours to reduce cutting and filling.
- Control roof water onsite (see Section 6.4 Vegetated Roofs and Section 6.6 Roof Rainwater Collection Systems for design guidelines).
- Use low impact foundations (see Section 6.5: Minimal Excavation Foundations).
- Limit clearing and grading to road, utility, building pad, landscape areas, and the minimum amount of extra land necessary to maneuver machinery. All other land should be delineated and protected from compaction with construction fencing. (see Chapter 4: Vegetation Protection, Reforestation, and Maintenance, and Chapter 5: Clearing and Grading).

LID in Green Cove Basin

The city of Olympia is using low impact development strategies and other environmental protection measures to preserve high quality forest and aquatic resources in Green Cove basin. One measure includes setting a maximum total impervious surface coverage of 2,500 square feet per lot (Title 18 Unified Development Code: Article II. Land Use Districts).